

temperature and physical conditions, arrangements were made to photograph the spectra of stars and nebulae, in order to test the view, employing a quite new basis of facts; this new basis of the inquiry consists of 443 photographs of 171 of the brighter stars.

Having this new and accurate basis of induction, the objects were to determine whether the hypothesis founded on eye observations is also demanded by the photographs, and in the affirmative case to discover and apply new tests of its validity, or otherwise.

The results as yet obtained are not sufficient to permit a discussion of all points bearing upon the new classification, but most of the crucial ones are certainly covered by the photographs already obtained.

The main instrument employed in the work has been a 6-inch refracting telescope, with an object-glass made and corrected for G by the Brothers Henry. This was at first used in conjunction

the proper angle to the larger telescope. When photographing the spectrum of a star, therefore, the star is first brought to the centre of the field of the large telescope, and the proper deviation is then given by reading off on the declination circle. This method has been found to work quite satisfactorily.

With this combination the exposure required for a first magnitude star is about twenty minutes. The method of mounting the prism is shown in Fig. 41.

For the fainter stars, the 6-inch prism of $7\frac{1}{2}^\circ$ has been adapted to a Dallmeyer rectilinear lens of 6 inches aperture and 48 inches focal length. At times prisms of $7\frac{1}{2}^\circ$ have been used on a 10-inch equatorial.

Since the spectrum of a point of light such as a star is a line so fine that the spectral lines would not be measurable, it is necessary to give it breadth. This is done by adjusting the prism so that the spectrum lies along a meridian of R.A. and altering the rate of the clock.

J. NORMAN LOCKYER.

(To be continued.)

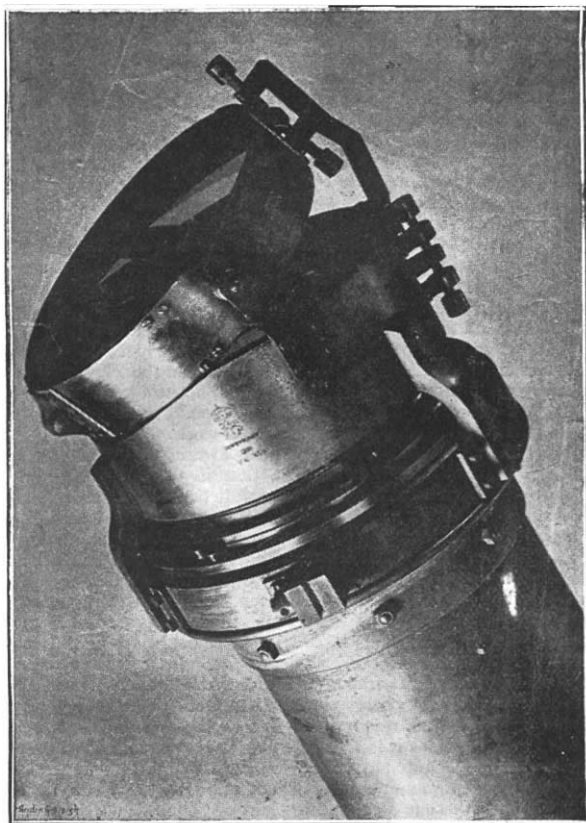


FIG. 41.—Objective prism fitted to object-glass.

with a prism of $7\frac{1}{2}^\circ$ of dense glass by Hilger. The object-glass and prism are fixed at the end of a wooden tube, which is attached to the side of the 10-inch equatorial, at such an angle that the spectrum of a star falls on the middle of the photographic plate when its image is at the centre of the field of the larger instrument. The camera is arranged to take plates of the ordinary commercial size, $4\frac{1}{4} \times 3\frac{1}{4}$ inches. The spectra obtained with this instrument are 0.6 inch long from F to K. An excellent photograph of the spectrum of a first magnitude star can be obtained with an exposure of five minutes. Afterwards a 6-inch prism, with a refracting angle of 45° , obtained from the Brothers Henry, was used with the Henry 6-inch object glass. The spectra obtained with the latter are two inches long from F to K, and the definition is exquisite. In some photographs the calcium line at H is very clearly separated from the line of hydrogen, which occupies very nearly the same position. It is unnecessary to swing the back of the camera in order to get a perfect focus from F to K. The deviation of the prism is so great that it would be very inconvenient to incline the tube which supports it at

THE IRON AND STEEL INSTITUTE.

THE annual summer meeting of the Iron and Steel Institute was held in Birmingham last week, commencing Tuesday, the 20th inst., and extending over Friday, the 23rd inst. Sir David Dale, the President, took the chair at the sittings for the reading of papers, and it may be said here that the meeting was remarkably successful throughout, being one of the pleasantest and most instructive gatherings that has been held for a long time past; both Mr. Brough, the Secretary of the Institute, and the local committee are to be congratulated on the excellence of their arrangements.

There were twelve papers down for reading and discussion, of which the following is a list:—

“On the Direct Puddling of Iron,” by E. Bonehill (Marchienne-au-Pont, Belgium).

“On the Production of Iron by a New Process,” by R. A. Hadfield, member of Council (Sheffield).

“On the Thermo-Chemistry of the Bessemer Process,” by Prof. W. N. Hartley, F.R.S. (Dublin).

“On the Hardening of Steel,” by H. M. Howe (Boston, U.S.A.).

“On the Mineral Resources of South Staffordshire,” by H. W. Hughes (Dudley).

“On the Iron Industry of South Staffordshire,” by D. Jones, Secretary of the South Staffordshire Ironmasters’ Association (Shifnal).

“On the Iron Industry of the South of Russia,” by George Kamensky (St. Petersburg).

“On Cooling Curves and Tests of Cast Iron,” by W. J. Keep (Detroit, U.S.A.).

“On the Analysis of Ferro-Chromium,” by E. H. Saniter (Wigan).

“On Small Cast Ingots,” by R. Smith-Casson (Birmingham).

“On Tests of Cast Iron,” by T. D. West (Sharpsville, Pennsylvania).

“On Nickel Steel,” by H. A. Wiggin (Birmingham).

The papers of Mr. West and Mr. Keep were taken as read, all the others being read and discussed.

On the members assembling on Tuesday morning, in the Council House of Birmingham Corporation, they were welcomed by the Mayor, and by the members of the local reception committee.

The first paper taken was that by Mr. D. Jones, on the iron industry of South Staffordshire. This was an interesting contribution, but mainly historical in its character. It dealt with the rise and progress of the iron industry of the district from its earliest days, and, in treating of more modern times, pointed out how the production of wrought-iron had decreased as steel had taken its place, although a good deal of puddled iron is still produced in the district. The paper of Mr. Hughes, on the mineral resources of South Staffordshire, was very much of the same character, and gave, in a convenient form, many facts relating to the subject.

M. Bonehill’s paper on the direct puddling of iron was next read. This process appears to be a revival of, and doubtless an improvement on, a method of puddling which was proposed, and to a limited extent carried out, in the earlier years of the century, but which never obtained any great hold in the iron

industry. It consists, briefly, in running molten iron from the blast furnace into a reservoir, and from thence letting it flow into the puddling furnace, the latter being of larger description than is generally used. It is obvious that with this process, as compared to the ordinary method of feeding the puddling furnace with cold pig, there is a saving of fuel, inasmuch as the metal does not require melting; on the other hand, the difficulty of getting a uniform product, owing to the inability to mix various kinds of pig, has to be overcome. Apparently the author has been successful in the latter respect, although how he has accomplished his end was not stated in the paper; the tests given, however, indicate that a superior quality of iron is produced.

Mr. Kamensky's paper on the iron industries of South Russia was, like the two first contributions, of an historical nature. In this case, however, there was less of ancient history in the memoir, and necessarily so, as the production of iron in Russia, as an industry of importance, is of essentially modern growth. It is true that iron-making has been carried on in Russia for a long time past, but it is only within the last year or two that any great strides have been made. Now, however, there are several works in operation, and it appears likely that more will follow; so Russia may in her turn put in a claim for a share of the opening markets of the world. This is a fact that British steel-makers may perhaps look on not altogether with satisfaction; but it is inevitable. Only by increased exertion can British manufacturers maintain their position in the markets of the world; but there is one point, however, worthy of attention. If Russia is about to start many steel works, large quantities of plant and machinery will be required. It is proposed that the Institute shall next year hold its summer meeting in Russia. The suggestion is a bold one, but is worthy of consideration, for it is only by pushing abroad that steel makers can hope to keep abreast of the times. The days are past when the manufacture of iron and steel was almost entirely centred in England. Now there are works all over the world, under intelligent and scientific management. It is unreasonable to expect that we, in England, will continue to originate all new and valuable processes, and it is well, therefore, that English manufacturers should go abroad to reap the advantages of foreign research and practice; just as foreign manufacturers have in times past, and are still, reaping the advantage of English experience and study.

The reading and discussion of the above four papers constituted the business of the first sitting. The afternoon of that day—Tuesday, the 20th inst.—was devoted to visits to works. One party proceeded to the Staffordshire Steel and Ingot Iron Company's establishment at Bilston, where the operations of rolling sections and plates were witnessed. A large quantity of basic steel is produced at these works; and the method of dealing with the basic slag, which is largely used for agricultural purposes, was inspected with interest by the members. Another party visited the Electric Construction Company's works at Wolverhampton; whilst, again, others distributed themselves amongst various works in Birmingham.

On assembling again on Wednesday morning the first paper taken was that contributed by Prof. Harley, on the thermochemistry of the Bessemer process. This was an exceedingly interesting paper, which those engaged in subjects of this nature would do well to read in full in the *Transactions* of the Institute. The author commenced by saying that the flame issuing from the mouth of a Bessemer converter was first investigated by Sir Henry Roscoe in 1863 (see *Manchester Literary and Philosophical Society's Proceedings*, vol. iii. p. 57, and *Philosophical Magazine*, vol. xxxiv. p. 437); by Leilegg (see *Sitzungsberichte Kaiserl. Akademie der Wissenschaften*, Wien, vol. lvi. part ii.); and by Marshall Watts in 1867 (see *Philosophical Magazine*, vol. xxxiv. p. 437); by Tunner (see *Dingler's Polytechnisches Journal*, vol. clxxviii. p. 465); by J. M. Silliman Rowan (*Philosophical Magazine*, vol. xli. p. 1); by von Lichtenfels (see *Dingler's Polytechnisches Journal*, vol. xcxi. p. 213); by Spear Parker (*Chemical News*, vol. xxii. p. 25); by Kupelwieser (*Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, No. 8, p. 59, 1868); by Brunner and Wedding in 1868 (see *Zeitschrift für das Berg-Hütten- und Salinenwesen im preussischen Staate*, vol. xxvii. p. 117, 1869); and also by A. Greiner in 1874 (see *Revue Universelle des Mines*, vol. xxxv. p. 623). Up to the present time the nature of the spectrum, the cause of its production, its sudden disappearance when decarburisation of the metal takes place, and the connection between the decarburisation of the metal and the extinction of the spectrum, have not been satisfactorily explained. According to Roscoe,

Leilegg, Kupelwieser, and Spear Parker, the spectrum is characterised by bands of carbon or of carbon monoxide, which disappear when all the carbon is burnt out of the metal. On the other hand, Simmler, Brunner, von Lichtenfels, and Wedding hold that the spectrum is not due to carbon, or to carbon monoxide, but to manganese and other elements in pig iron. Dr. Marshall Watts had come to the conclusion that it was not the spectrum of carbon in any form, nor of manganese, but that of manganetic oxide. Leilegg proved that carbon monoxide yields a continuous spectrum, which causes the bright spectrum of the Bessemer flame; but he also attributed certain lines, or bands, to the high temperature of the carbon monoxide. Marshall Watts established the fact that six lines of the spectrum of iron were present in the Bessemer spectrum; Greiner observed in flame from highly manganiferous pig iron the spectrum of manganese. The author concluded this part of his paper by pointing out the fact that notwithstanding the great advance which has been made in spectroscopy during the last twenty years, our knowledge of flame spectra has remained almost stationary, although much attention has been directed to the spectra of the elements as we obtain them at higher temperatures by vapourising substances in the electric arc, and by the transmission of electric sparks.

Prof. Hartley next proceeded to describe a method of accurately investigating the Bessemer flame. He pointed out that the determination of wave-length of lines and bands by eye observation only, with instruments of the usual form, is laborious under the most advantageous conditions, but it is especially so when the spectra are constantly changing; and it becomes practically impossible when the lines and bands to be measured are in the ultra-violet. Spectra which are recorded by photography are capable of being more accurately measured at leisure by very simple means; moreover, they constitute a permanent record; and for accurate observations, determinations of wave-lengths are absolutely essential. The author next went on to describe a modification of the instrument he had originally designed for this purpose. This is described in the *Proceedings* of the Royal Dublin Society, and also in Thorpe's "Dictionary of Applied Chemistry," article "Spectroscope." This instrument was especially designed for use in steel work, particularly for studying the spectra of flames and heated gases of open-hearth furnaces. It was therefore desirable that it should give a fair amount of dispersion at the less refrangible end of the spectrum. A train of four quartz prisms was at first arranged, and a camera was fitted with a rack and pinion movement to the frame holding the dark slide, so that as many as thirty spectra could be photographed on one plate. The stand, however, was found to be too light. Instead of four quartz prisms, a single prism of calcite may be employed if the surfaces are well protected from dust; the prism table was fixed so that it could be placed in almost any required position. The camera was of metal with an eye-piece behind the frame for the dark slide, so as to make it available for visual observation. In a circular box at the end of the camera, which was reduced in size, the dark slide can be fixed at any angle, as it is rotated by means of a toothed wheel. The prisms move automatically with the camera, and in order to secure the minimum angle of deviation to the mean rays photographed there is a condensing lens of 3-inch focus. There is a slit plate, covered with thin quartz to exclude dust and dirt, and upon this the image of the flame was projected. A metal plate, with a V-shaped piece cut out at one end, slides over the slit plate, and serves to shorten or lengthen the slit and secure a greater or smaller number of spectra on one photographic plate. In some cases a photograph was taken every half-minute, from the commencement to the termination of the "blow." This could be accomplished only by the use of the arrangement described, as the plates were no more than 3 inches by 2½ inches. The instrument was focussed by a photograph of sun spectra.

The author also described an ingenious arrangement consisting of yellow cloth, with armholes and sleeves fitted with elastic, by means of which he carried on development of the photographs without use of a dark room. By this apparatus it was shown that a large number of lines in the spectrum of the Bessemer flame were coincident with lines in the solar spectrum, and the position of the lines and edges of bands with respect to the sodium line was recorded, being measured with a micrometer screw and microscope. Enlargements were made in which the spectra were magnified ten diameters. Several interpolation curves were drawn by which linear measurements were

reduced to oscillation-frequencies, and by means of Barlow's mathematical tables these were reduced to wave-lengths which are the reciprocals of the oscillation-frequencies. The author then went on to describe some of the difficulties met with in obtaining measurements of bands, due to alterations in width, or to their becoming less distinct at the edges. The question is dealt with in "Flame Spectra of High Temperatures," *Philosophical Transactions*, 1894, part 1.

Prof. Hartley had carried out experiments at Crewe, and at Dowlais, in South Wales. Results obtained by photography of the spectrum of the Bessemer flame were given in the paper. For the details we must refer our readers to the original memoir. As the author pointed out, the Bessemer spectrum is a complex one, which exhibits differences in constitution during different periods of the blow, and even during different intervals of the same period. Watts had observed that the spectrum differs in different works, owing to variations of temperature and the composition of the metal blown. After discussing the various opinions held by previous investigators as to the utility of spectrum analysis in steel making—on which subject inquirers are by no means agreed—the cause of the non-appearance of lines at the termination of the blow is discussed. Prof. Hartley then proceeded to what was perhaps the most interesting part of his paper, namely, the temperature of the Bessemer metal and of the flame, and the use of the spectrum as an index of temperature. Watts concluded that though the temperature of the flame was above the melting point of gold, it was below that of platinum. Le Chatelier (*Comptes rendus*, vol. cxiv. p. 670) was of opinion that the temperature of the Bessemer converter during the boil is 1330° C., at the finish 1580° C., while the steel in the ladle is at 1640° C. There is no measure of the temperature at the hottest period of the boil, and unless the metal in the converter is cooled during the last minute of the blow, which some of the author's photographs indicated, it was difficult to understand how its temperature could be raised by the addition of the cooler spiegeleisen and ferro-manganese. The rise of temperature at this period could be accounted for by the after-blow. Of course when the metal is charged with oxygen, the additional spiegeleisen, containing carbon and manganese, would cause the combustion of these elements. When the oxyhydrogen flame spectra of the manganese, magnetic oxide of iron, and ferric oxide are photographed, the number of lines and bands in the spectra are not more numerous than with a Bessemer flame spectrum of only half a minute's exposure, although the above spectra may have received any exposure from thirty to eighty minutes. When a substance emits a spectrum composed of bands and lines, it is evidence of the presence of the substance in the flame in a state of glowing vapour; when the same substance emits two spectra, one differing from the other by the largely increased number of bands or lines, it is evidence that either the substance is more copiously vapourised, or that the temperature of the vapour is higher. When a simple spectrum changes to one of a more complex character, the alteration is due to an increase in temperature, other things being equal. Similarly when a spectrum extends through the visible rays into the ultra-violet region, and an increase is observed in the number and intensity of the ultra-violet rays, nothing but an increase of temperature will serve to account for the change in the spectrum. No increase of material in the flame would increase the refrangibility of the rays emitted by its vapour; hence the study of the ultra-violet spectra of flames by the photographic method becomes an important line of investigation.

After pointing out the difficulty of ascertaining the maximum temperature of any flame (as such temperature may exist over but a very small area), and giving an instance, the author states that Le Chatelier's recent measurements of the temperature of furnaces have given numbers considerably lower than those usually accepted. Langley's estimate of the temperature of the Bessemer flame at 2000° C.—because platinum appears to be rapidly melted in it—is not to be relied upon. Le Chatelier finds that the metal is not fused but dissolved in drops of molten steel. Marshall Watts observed that the sodium lines 5681 and 5687 may be employed as an index of temperature, since they are present in the spectrum of any flame containing sodium the temperature of which is hot enough to melt platinum, but they do not appear at lower temperatures. The Bessemer flame does not show this double line, but only the D lines, neither does it show lithium orange lines, which appear at a somewhat lower temperature. It may therefore be concluded

that the flame is not hot enough to produce these lines. The proportion of sodium in the Bessemer flame is evidently very small from the narrowness and want of intensity of the D lines, and the fact that they are not seen reversed in any spectrum; hence, though the temperature may be high enough, the quantity of material present is not sufficiently large to yield the lines 5681 and 5687.

We have not space to follow the author in all the interesting details of his reasoning, but we have perhaps said enough to indicate his line of thought. He later points out that, judging by the number of lines and bands belonging to iron and manganese, which have been photographed in the spectrum of the Bessemer flame, the temperature must in any case nearly approach that of the oxyhydrogen flame, even if it does not very generally exceed it. The paper concluded with particulars of the heat of combustion of the oxidisable impurities in pig iron. He calculates, as far as data are available, the absolute heating effect of such oxidation. The temperature retained according to these calculations amounts to 1454° C. above that of molten cast iron. This, however, is a theoretical value, and allowance must be made for the specific heats of the gases, the metal, and the slag, which are greater at the elevated temperatures than at the temperatures at which the numbers representing specific heats were determined. The specific heat of the converter must be considerable, but it must be remembered that it is already heated to the temperature of the molten metal; but even if we allow that 50 per cent. of the heat is absorbed, or conveyed away, we should then have the temperature 727° C. above that of the molten pig iron; and thus, with grey iron, at 1220° C. the metal may have acquired a temperature of more than 1947° C., which is very considerably above the melting point of platinum.

The discussion which followed the reading of this paper was interesting, but no new points of importance were added. Mr. Baerman considered that the author was right in laying stress on the temperature of the flame as well as on the materials in the converter. Mr. J. Stead pointed out that some of the calculations were made in cases where the composition of the metal was very different to that common in England. Mr. Tucker also pointed out the difficulty in arriving at any conclusion owing to the variation in metal used, and he referred to the effect of a temperature of dissociation which might be obtained if the metal were sufficiently rich in silicon. His own experiments supported those of Prof. Hartley, that the temperature was certainly at times considerably above the melting point of platinum, and he was inclined to think that the temperature of dissociation was often reached.

The next paper was also one of considerable scientific interest. It was Mr. Howe's contribution on the hardening of steel, and was read in abstract by Mr. Brough, the Secretary of the Institute. As the paper had been received so recently, copies of it had not been distributed, and it was manifestly impossible to discuss a memoir of this abstruse nature at first sight, especially as the paper was not read in full. It was therefore wisely determined to have the text corrected, after which the paper will be distributed, and its discussion taken at the next meeting in May. For the present, it will suffice to say that the author deals largely with the vexed problem of the allotropic state of iron. It would have been a pity to have discussed the paper on the spot, as neither Prof. Roberts-Austen nor Prof. Arnold were present; neither had M. Osmond been able to send his usual written contribution. In fact, the only person present whose name has become at all prominently identified with the states of iron treated was Mr. Hadfield, who spoke briefly, saying that he had not had time to master the paper. We will, therefore, defer our abstract of this memoir until the time comes to give an account of the next meeting.

Mr. R. A. Hadfield's paper on the production of iron by a new process was next read. The author's object has been to obtain a pure iron; for which purpose he had had recourse to aluminium as an agent. The first result was that he made an alloy of iron and aluminium very rich in the latter constituent, there being no less than 36 per cent. present. In spite of being a failure, so far as the object in view was concerned, a very interesting result was obtained; for although there was no more than a trace of carbon present, the alloy was hard enough to scratch glass. Proceeding on the same lines, however, and working with ferrous oxide and granulated aluminium, a sample of iron containing 99.75 per cent. of that metal was finally obtained at the very moderate cost of about eighteen pence per pound.

Mr. Saniter's paper, describing a new method for the analysis of chrome and ferro-chromium, was the last read at this sitting. This is a further extension of Mr. Stead's modification of Dr. Clarke's process, and has the great advantage of reducing the time occupied in the analysis.

On the afternoon of this day there were several excursions, the chief of which was to Worcester, where the works of the Royal Porcelain Company were inspected. Another party visited the Round Oak Iron and Steel Works, while others proceeded to the glass works, fireclay works, small arms factories, and to other works in and around Birmingham. In the evening there was a very successful reception and entertainment in the Edgbaston Botanical Gardens.

The final sitting of the meeting was on Thursday of last week, when a paper by Mr. Henry Wiggin, on nickel steel, was first taken. In this contribution the advantages of nickel steel as a constructive material were brought forward; its great tensile strength combined with excessive ductility being dwelt upon. Another advantage possessed is freedom from corrosion, as compared with ordinary steel. Instances were given of the nickel steel containing $3\frac{1}{2}$ per cent. of nickel, which had a tensile strength fully 30 per cent. higher than ordinary steel, and an elastic limit at least 75 per cent. higher. The author does not give any details in regard to cost, which is naturally higher than that of ordinary steel; but speaking upon the subject generally, he was of opinion that the additional price that would have to be charged would generally be more than compensated for by increased efficiency. In the discussion, Mr. W. Beardmore, of Glasgow, said he had been making large quantities of nickel steel for the last two years. This was for armour-plates, but he was now preparing a series of tests to submit to Lloyd's with a view to introducing the material for marine purposes. Mr. Jeremiah Head, who had lately visited America, said that at the works of Mr. Carnegie he had seen large quantities of nickel steel produced at a cost, he was told, of about £7 a ton; but there natural gas of great richness was available. Mr. Thompson, of New York, who had been largely engaged in the manufacture of nickel steel, said that in America 50,000 to 75,000 tons of this material had been produced during the last three years. A German chemist had found that with an alloy of 15 per cent. of nickel almost a new metal was made having a tensile strength of 244,000 lbs. to the square inch, and an elastic limit as high in proportion. He estimated that to build a large battleship of nickel steel would add but 2 per cent. to her cost, whilst the efficiency would be doubled. Mr. Thomas Turner afterwards pointed out that nickel steel was supposed to have a wide range of extension and contraction with variations of temperature, so that if a ship went to the polar regions it might become even feet shorter in its length.

Mr. Smith-Casson's paper, on small cast ingots, was next read. The author claims to have got very good results by casting ingots together from the bottom. This was the last paper read at the meeting.

Thursday afternoon was devoted to an excursion to Stratford-on-Avon, whilst on the following day, Friday, an excursion was made to Kenilworth and to Warwick, where members and their friends were entertained at the Castle by Lord and Lady Warwick.

THE SPECTRUM OF HELIUM.¹

IN the *Chemical News* for March 29 last (vol. lxxi. p. 151), I published the results of measurements of the wave-lengths of the more prominent lines seen in the spectrum of the gas from clèveite, now identified with helium. The gas had been given to me by the discoverer, Prof. Ramsay; and being from the first batch prepared, it contained other gases as impurities, such as nitrogen and aqueous vapour, both of which gave spectra interfering with the purity of the true helium spectrum. I have since, thanks to the kindness of Profs. Ramsay and J. Norman Lockyer, had an opportunity of examining samples of helium from different minerals and of considerable purity as far as known contamination is concerned. These samples of gas were sealed in tubes of various kinds and exhausted to the most luminous point for spectrum observations. In most cases no internal electrodes were used, but the rarefied gas was illuminated solely by induction, metallic terminals being attached to the outside

of the tube.¹ For photographic purposes a quartz window was attached to the end of the tube, so that the spectrum of the gas could be taken "end on."

My examinations have chiefly been made on five samples of gas.

(1) A sample from Prof. Ramsay in March last. Prepared from clèveite.

(2) A sample from Prof. Ramsay in May last. Prepared from a specimen of uraninite sent to him by Prof. Hillebrand. Gas obtained by means of sulphuric acid; purified by sparking.

(3) A sample from Prof. Ramsay in June last. Prepared from bröggerite.

(4) A sample from Prof. Lockyer in July last. Prepared by a process of fractional distillation from a sample of bröggerite sent by Prof. Brögger.

(5) A sample of gas from Prof. Ramsay, "Helium Purissimum." This was obtained from mixed sources, and had been purified to the highest possible point.

In the following table the first four samples of gas will be called:—(1) "Clèveite, R."; (2) "Uraninite, R."; (3) "Bröggerite, R."; and (4) "Bröggerite, L." Only the strongest of the lines, and those about which I have no doubt, are given. The wave-lengths are on Rowland's scale.

The photographs were taken on plates bent to the proper curvature for bringing the whole spectrum in accurate focus at the same time. The spectrum given by a spark between an alloy of equal atoms of mercury, cadmium, zinc, and tin, was photographed at the same time on the plate, partially overlapping the helium spectrum; suitable lines of these metals were used as standards. The measurements were taken by means of a special micrometer reading approximately to the $1/100,000$ th inch, and with accuracy to the $1/10,000$ th of an inch. The calculations were performed according to Sir George Stokes's formula, supplemented by an additional formula kindly supplied by Sir George Stokes, giving a correction to be applied to the approximate wave-lengths given by the first formula, and greatly increasing the accuracy of the results.

Wave-length.	Intensity.	
7065·5	5	A red line, seen in all the samples of gas. Young gives a chromospheric line at 7065·5.
6678·1	8	A red line, seen in all the samples of gas. Thalén gives a line at 6677, and Lockyer at 6678·3. Young gives a chromospheric line at 6678·3.
5876·0	30	The characteristic yellow line of helium, seen in all the samples of gas. Thalén makes it 5875·9, and Rowland 5875·98. Young gives a chromospheric line at 5876.
5062·15	3	
5047·1	5	A yellow-green line, only seen in "Helium Puriss." and in "Bröggerite, R." and "L." Thalén gives the wave-length as 5048.
5015·9	7	A green line seen in all the samples of gas. Thalén gives the wave-length 5016. Young gives a chromospheric line at 5015·9.
4931·9	3	
4922·6	10	A green line, seen in all the samples of gas. Thalén gives the wave-length 4922. Young gives a chromospheric line at 4922·3.
4870·6	7	A green line, only seen in "Uraninite, R." Young gives a chromospheric line at 4870·4.
4847·3	7	A green line, only seen in "Uraninite, R." Young gives a chromospheric line at 4848·7.
4805·6	9	A green line, only seen in "Uraninite, R." Young gives a chromospheric line at 4805·25.
4764·4	2	There is a hydrogen line at 4764·0.
4735·1	10	A very strong greenish blue line, only seen in "Uraninite, R."
4713·4	9	A blue line, seen in all the samples of gas. Thalén's measurement is 4713·5. Young gives a chromospheric line at 4713·4.
4658·5	8	A blue line, only seen in "Uraninite, R."
4579·1	3	A faint blue line, seen in "Uraninite, R." Lockyer gives a line at 4580, from certain minerals. I can see no traces of it in the gas from Bröggerite. A hydrogen line occurs at 4580·1.

¹ *Journal of the Institution of Electrical Engineers*, part 91, vol. xx., Inaugural Address by the President, William Crookes, F.R.S., Jan. 15, 1891.

¹ From the *Chemical News*, August 23.